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(71)Applicant : NIPPON STEEL CORP
(72)Inventor : TAKADA TAKESHI
YAMAMOTO AKIO

(54) FERRITIC STAINLESS STEEL PLATE FOR BELLOWS

(57)Abstract:
PURPOSE: To provide a ferritic stainless steel plate for bellows, excellent in stress corrosion cracking resistance.
CONSTITUTION: This ferritic stainless steel plate for bellows has a composition consisting of, by weight, ≤0.02% C, 10.0-23.0% Cr, ≤0.015% N, and Fe with inevitable impurities, further containing, if necessary, ≤1.0% Si and ≤1.0% Mn, further containing, if necessary, either or both of Nb in the amount ≥7times the total content of C and N and not higher than 0.6% and Ti in the amount ≥4times the total content of C and N and not higher than 0.6%, and further containing, if necessary, one or ≤2 kinds among ≤2.0% Mo, ≤1.0% Ni, and ≤0.8% Cu. Moreover, in this steel plate, surface roughness is regulated to 0.04-0.5μm by arithmetic mean roughness Ra and to 0.2-2.00μm by maximum height Rv.

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CLAIMS

[Claim(s)]

[Claim 1] It is C at weight %. : 0.02% or less, less than [more than Cr:10.0 23.0%], N : Ferritic-stainless-steel board for bellows to which surface roughness is characterized by 0.2-micrometer or more being 2.00 micrometers or less by arithmetic mean granularity Ra in the ferritic stainless steel containing 0.015% or less in 0.04-micrometer or more 0.5 micrometers or less and the maximum depth Rv.

[Claim 2] It is C at weight %. : 0.02% or less, less than [Si:1.0%], less than [Mn:1.0%], Cr: Less than [more than 10.0 23.0%], N : It is a Nb:C content (%) further 0.015% or less. N content (%) It is 7 or more times of the sum, and is 0.6%or less Ti:C content (%). N content (%) Are 4 or more times of the sum, and 0.6% or less of one sort or two sorts are included. In addition, the ferritic-stainless-steel board for bellows to which surface roughness is characterized by 0.2-micrometer or more being 2.00 micrometers or less by arithmetic mean granularity Ra in the ferritic stainless steel which consists of an unescapable impurity and Fe in 0.04-micrometer or more 0.5 micrometers or less and the maximum depth Rv.

[Claim 3] It is C at weight %. : 0.02% or less, less than [Si:1.0%], less than [Mn:1.0%], Cr: Less than [more than 10.0 23.0%], N : Further 0.015% or less Less than [Mo:2.0%], In the ferritic stainless steel which consists of an unescapable impurity and Fe, including one sort less than [nickel:1.0%] and not more than Cu:0.8%, or two sorts or more The ferritic-stainless-steel board for bellows with which surface roughness is characterized by being 0.2 micrometers or more 2.00 micrometers or less in 0.04-micrometer or more 0.5 micrometers or less and the maximum depth Rv by arithmetic mean granularity Ra.

[Claim 4] It is C at weight %. : 0.02% or less, less than [Si:1.0%], less than [Mn:1.0%], Cr: Less than [more than 10.0 23.0%], N : It is a Nb:C content (%) further 0.015% or less. N content (%) It is 7 or more times of the sum, and is 0.6%or less Ti:C content (%). N content (%) Are 4 or more times of the sum, and 0.6% or less of one sort or two sorts are included. Furthermore, one sort less than [Mo:2.0%], less than [nickel:1.0%], and not more than Cu:0.8% or two sorts or more are included. In addition, the ferritic-stainless-steel board for bellows to which it is the ferritic stainless steel which consists of an unescapable impurity and Fe, and surface roughness is characterized by 0.2-micrometer or more being 2.00 micrometers or less by arithmetic mean granularity Ra in 0.04-micrometer or more 0.5 micrometers or less and the maximum depth Rv.

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DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[Industrial Application] this invention relates to the ferritic stainless steel for bellows used for piping of an automobile exhaust air system and gas, and a water pipe.
[0002]
[Description of the Prior Art] The bellows pipe is used for the purpose of absorbing the distortion and vibration by heat as piping, such as a gas and a liquid. Conventionally, the copper alloy and the austenitic stainless steel have been used for this bellows. This reason is because it was difficult with the metal of others [processing / to bellows structure]. That is, a copper alloy and an austenitic stainless steel have the large elongation between the colds, and it is the optimal material for the bellows which applies bulging fabricated by elongation. On the other hand, since ductility ran short, bulging of the metal which consists of bcc crystals, such as carbon steel, was not completed.
[0003] On the other hand, depending on the corrosive solution passing through the interior, there was a fault that stress corrosion cracking tends to generate the bellows made from an austenitic stainless steel although manufacture is easy. In order to absorb distortion and vibration by bending of the mountain for heights of a pipe, and the valley for a crevice, stress surely applies [this] bellows to a part for a part for heights, and a crevice. That is, removal of stress is impossible structure and parts. Nevertheless, an austenitic stainless steel is the high alloy of stress corrosion crack sensitivity. For this reason, the bellows made from an austenitic stainless steel had the fault of being very easy to generate stress corrosion cracking.
[0004] In order to avoid stress corrosion cracking, it is one of whether it considers as the structure where whether a low material of stress corrosion crack sensitivity being used and the structure, i.e., a stress load, where stress corrosion cracking cannot occur easily structurally do not remain. In order to reduce the stress corrosion crack sensitivity of an austenitic stainless steel, nickel content is made to increase and reducing Cr, N, Mo, and P is proposed as indicated by JP,49-107915,A. However, even if it used such steel, by the time it prevented generating of stress corrosion cracking only by the time to stress-corrosion-cracking generating being extended suitably, it did not result.
[0005] On the other hand, the number of the irregularity of bellows is increased structurally, or it is making angle of bend of a crevice or heights small, and considers reducing the stress which distributes stress and is applied to each crevice or heights. However, since bellows became large or became long, this method had the fault to which cost becomes high -- equipment also has the need of enlarging. And still, it did not cancel but the susceptibility of stress corrosion cracking has been afflicted by stress corrosion cracking depending on environment.
[0006] On the other hand, this invention person etc. succeeded in manufacturing the bellows which limited the surface roughness of a ferritic-stainless-steel board, and canceled stress corrosion crack sensitivity as a matter of fact.
[0007]
[Problem(s) to be Solved by the Invention] However, although it succeeded in processing of the bellows of a ferritic stainless steel, the fracture accident presumed to be based on the shortage of ductility of a material at the mountain portion of bellows or the edge of a processing part especially at the time of processing was produced in many cases, and the yield was **** very much compared with processing of an austenitic stainless steel. Then, in order to improve the ductility of a material, it examined by reducing C and N to a limit based on knowledge conventionally, and raising the ductility of a material. However, although the ductility by the tension test of a material improved, fracture accident did not necessarily decrease at the edge of the mountain portion of bellows, or a processing portion. Furthermore, although the influence by inclusion or the sludge was considered and the fracture fracture surface was observed in detail, it did not come to check them.
[0008] Thus, it was surmised that the processing crack at the time of bellows processing had a cause in the shortage of ductility of a material and properties other than existence of inclusion and a sludge. this invention is to utilize the knowledge and offer the ferritic stainless steel which raises the yield productivity of bellows processing without crack generating based on having found out that generating of a crack related to surface irregularity.
[0009]
[Means for Solving the Problem] this invention person etc. admitted that the irregularity of a material originated and destruction occurred as causes other than the shortage of ductility, and existence of inclusion and a sludge, as a result of performing examination detailed about the cause of generating of the destruction generated at the time of bellows processing of a ferritic stainless steel. That is, stress concentrated on the portion to which board thickness is small locally with the irregularity on the

front face of a material, and the phenomenon which fracture generates with there [as the starting point] was found out. It is common sense for this contractor that fracture occurs from the notching section in the tension test which added notching. However, when compared with notching of a test piece, it newly found out that concentration of local stress occurred and the irregularity on a small minute front face might also serve as an origin of fracture overwhelmingly.

[0010] Then, this invention person etc. is stopping the minute irregularity on a front face as much as possible, and tried to reduce the processing crack of bellows as much as possible. The hydrostatic bulge test was performed by the ferritic stainless steel to which arithmetic mean granularity Ra of ****** was reduced as much as possible first, and crack nature was evaluated. Bulging was performed until it fractured, and the examination estimated crack sensitivity from the forming height at the time of fracture. In an exam, a processing crack [in / bellows processing / in the one where the forming height at the time of fracture is larger] shall decrease. However, by reducing Ra, on the average, although forming height rose, in inside, what has extremely low forming height generated it. And when [this] the surface state of a material with low forming height was analyzed in detail extremely, compared with the material of forming height with the average value of the maximum depth Rv, the large thing became clear. However, the more Ra and the value of Rv were small, forming height did not become high but, the more they were also understood that there is a limitation. This reason is presumed for the lubrication between the metal mold which presses down a part for a flange to become inadequate from the surface situation of mold goods, and for elongation to concentrate at the peak of bulging although it is under examination wholeheartedly.

[0011] this invention is made based on the above knowledge. The 1st invention is the ferritic stainless steel which reforms a surface state based on the material which has high ductility, limited the upper limit of Content C and the amount of N in order to secure sufficient ductility of the material itself, and limited the upper limit of Rv. That is, at weight %, it is C. : 0.02% or less Less than [more than Cr:10.0 23.0%], N : In the ferritic stainless steel containing 0.015% or less, surface roughness is the ferritic-stainless-steel board for bellows characterized by 0.2-micrometer or more being 2.00 micrometers or less by arithmetic mean granularity Ra in 0.04-micrometer or more 0.5 micrometers or less and the maximum depth Rv.

[0012] Moreover, bellows is used in many cases with absorption and the fused salt corrosive environment of an intense vibration or distortion. For oscillating absorption and distorted absorption, still more sufficient ductile reservation for a material is required. therefore, Ti -- and -- or steel which added Nb is considered as the 2nd invention That is, it is C at weight %. : 0.02% or less, Si: Less than [1.0%], less than [Mn:1.0%], Cr: Less than [more than 10.0 23.0%], N : It adds further 0.015% or less. Are 7 or more times of the sum of a Nb:C content and N content, are 4 or more times of the sum of 0.6% or less, a Ti:C content, and N content, and 0.6% or less of one sort or two sorts are included. In addition, it is the ferritic stainless steel which consists of an unescapable impurity and Fe. Surface roughness is the ferritic-stainless-steel board for bellows characterized by 0.2-micrometer or more being 2.00 micrometers or less by arithmetic mean granularity Ra in 0.04-micrometer or more 0.5 micrometers or less and the maximum depth Rv.

[0013] On the other hand, the gas and liquid which pass through the interior may be applied to a corrosive high object. It is effective to add one sort of Mo, Cu, and nickel or two sorts or more corresponding to the corrosion-resistant level demanded for such a use, and such a ferritic stainless steel is considered as the 3rd invention. That is, at weight %, it is C. : 0.02% or less, Si: Less than [1.0%], less than [Mn:1.0%], Cr: Less than [more than 10.0 23.0%], N : 0.015% or less is contained. further Less than [Mo:2.0%], One sort less than [nickel:1.0%] and not more than Cu:0.8% or two sorts or more are included. Surface roughness is the ferritic-stainless-steel board for bellows characterized by 0.2-micrometer or more being 2.00 micrometers or less by arithmetic mean granularity Ra in 0.04-micrometer or more 0.5 micrometers or less and the maximum depth Rv.

[0014] Furthermore, to the bellows used in intense oscillating absorption and a corrosion foods environment, addition of addition and Mo of Ti or Nb, and nickel and Cu is effective, and considers this ferritic stainless steel as the 4th invention. That is, at weight %, it is C. : 0.02% or less, Si: Less than [1.0%], less than [Mn:1.0%], Cr: Less than [more than 10.0 23.0%], N : 0.015% or less is included. Furthermore it is 7 or more times of the sum of a Nb:C content and N content, and is 4 or more times of the sum of 0.6% or less, a Ti:C content, and N content, and 0.6% or less of one sort or two sorts are included. further again Less than Mo:2.0%], One sort less than [nickel:1.0%] and not more than Cu:0.8% or two sorts or more are included. In addition, it is the ferritic stainless steel which consists of an unescapable impurity and Fe. Surface roughness is the ferritic-stainless-steel board for bellows characterized by 0.2-micrometer or more being 2.00 micrometers or less by arithmetic mean granularity Ra in 0.04-micrometer or more 0.5 micrometers or less and the maximum depth Rv.

[0015] Next, the reason for limitation of this invention is explained. Although C dissolves to an invaded type and intensity is made to increase, it is the element in which ductility is reduced. So, in order [being enough] to carry out ductility reservation, the upper limit was made into 0.02% by weight %. Si is an element which degrades hot-working nature. So, the upper limit was limited with 1.0% by weight %.

[0016] Mn is an effective element in order to make S which is the detrimental impurity which lowers hot-working nature fix. However, processing of bellows will become difficult, if a lot of addition reduces ductility and it adds especially exceeding 1.0%. Then, the addition was made into 1.0%. Although Cr is the fundamental component of stainless steel, a lot of addition reduces ductility. Then, the upper limit was made into 23.0% by weight %. The minimum could be 10.0% in order to secure corrosion resistance.

[0017] Ti and Nb are the dissolution elements of powerful C and N, and decrease Dissolution C and the amount of N. Consequently, ductility improves. Since the addition needed to make C and N fix completely in stoichiometry as TiC and TiN, or NbC and NbN, in the case of Ti, it made the minimum 4 times of the amount of content C, and the amount of content N by weight %, and, in Nb, made it 7 times. However, it was set up by Ti, and since it became remarkable Dissolution Ti and ductility falling

the addition which exceeds 1.0% exceeding 0.6% the case of Ti in Nb according to a Nb independent, the upper limit was set up with 1.0% by Nb 0.6% by weight %. N has the same effect as C. So, since it had sufficient ductility for bellows processing, in N, the upper limit was made into 0.015% by weight %.

[0018] Although both Mo, nickel, and Cu are effective in raising corrosion resistance, a lot of addition reduces ductility. Especially, in the case of Mo, 2.0%, in the case of nickel, if it adds exceeding 0.8% in 1.0% and Cu, ductility will fall, and processing of bellows becomes difficult. Then, it limited in Mo and, as for the case of Cu, it limited the addition with 0.8% or less 1.0% or less with nickel 2.0% or less.

[0019] On the other hand, the value of arithmetic mean granularity Ra and the maximum depth Rv was limited from evaluation of forming height from the result of a hydrostatic bulge test. If Ra and Rv are large, stress will concentrate and fracture to the irregularity on a minute front face. However, even if Ra and Rv are too small, forming height decreases. This was considered because lubrication with metal mold fell at the time of processing of bellows. Then, 0.04-micrometeror more 0.5 micrometers or less and Rv were limited for Ra to processing of bellows with 0.2 micrometers or more 2.00 micrometers or less from evaluation of the forming height of a hydrostatic bulge test as a surface state of the steel plate which a crack does not produce.

[0020]

[Function] this invention offers the ferritic stainless steel for bellows processing which can decrease the destruction which is easy to generate at the time of processing to bellows. The ferritic stainless steel of a base material becomes possible [securing the difference of the path of the heights of bellows, and a crevice enough] by limiting the content of C and N to low level. Furthermore, the lubrication to a lubricating oil with the metal mold at the time of bellows processing succeeds in fabrication of bellows without a processing crack in the good state by setting Ra to 0.04 micrometers or more 0.5 micrometers or less, and setting the value of Rv to 0.2 micrometers or more 2.00 micrometers or less. Consequently, the yield improves because the processing crack from which minute irregularity becomes a cause decreases and the crack at the time of bellows processing decreases remarkably.

[0021] When a material component reduces 0.02% or less and the amount of content N for the amount of content C even to 0.015% by weight % by weight %, ductility is fully secured. Moreover, still higher ductility is secured by depositing C and N as Ti and a Nb compound by addition of Ti and Nb, and it becomes usable as a material for bellows in the environment where intense oscillating absorption or absorption of distortion is required. The lower limit made Ti and Nb addition 4 times of the sum of the amount of content C, and the amount of content N by Ti, and made them 7 times of the sum of the amount of content C, and the amount of content N by Nb. A upper limit can secure the high ductility demanded by considering as 1.0% by0.6 and Nb by weight % at Ti. Addition of Mo, nickel, and Cu raises the corrosion resistance of a material, and can offer the material for bellows used under the environment where corrosion resistance is required by those addition.

[0022]

[Example] The bellows tubing test result of the steel plate which contains the chemical composition shown in Table 1 as A-H, respectively is shown with arithmetic mean granularity Ra and the maximum surface depth Rv. The value of Rv was measured based on the test method of JISB0601. The cut-off value was [the evaluation length of measurement conditions] 4mm in 0.8mm. The result of a bellows processing examination was performed by the existence of a crack.

[0023] From Table 1, the crack by bellows processing was not generated in No.A-E which is this invention steel. This invention steel and comparison steel are [0.04 micrometeror more 0.5 micrometers or less and Rv of Ra] 0.2 micrometers or more 2.00 micrometers or less. However, a processing crack produces the comparison steel F and Rv is 2.00 micrometers or more. Moreover, in the comparison steel G which the processing crack produced similarly, Ra is smaller than 0.04 micrometers. In the comparison steel F, minute irregularity exists on a front face and what the crack generated because the stress at the time of processing concentrates on this irregularity is presumed. On the other hand, in the comparison steel G, although there is little irregularity with a conversely minute front face, lubrication with metal mold is presumed to be what broke because the stress added at the time of processing does not join the whole material but concentrates on eye an inadequate hatchet only at bellows heights. Moreover, although the comparison steel H has Ra and Rv in a generic claim, since the amount of content C is over 0.02%, what the ductility insufficient shell bellows processing crack of the material itself produced is presumed.

[0024]

[Table 1]

No.	C	Si	Mn	Cr	Ti	N	Ni	Mo	Nb	Cu	Ra (μm)	Rv (μm)	加工試験	
A	0.012	0.25	0.33	16.30	0.37	0.010	0.05	—	—	—	0.06	1.26	割れ無し	発明鋼
B	0.010	0.50	0.01	11.05	0.23	0.005	—	—	—	—	0.04	0.24	割れ無し	
C	0.005	0.34	0.50	16.10	—	0.008	—	—	—	—	0.24	0.92	割れ無し	
D	0.001	0.11	0.09	17.14	0.18	0.010	—	1.2	—	—	0.07	0.40	割れ無し	
E	0.013	0.30	0.12	19.15	—	0.010	—	—	0.40	0.60	0.20	0.35	割れ無し	
F	0.005	0.10	0.13	17.20	0.23	0.007	—	—	—	—	0.20	2.10	割れ発生	比較鋼
G	0.013	0.30	0.15	19.15	0.05	0.015	—	—	—	—	0.03	1.00	割れ発生	
H	0.047	0.44	0.33	18.27	—	0.003	—	—	—	—	0.06	1.22	割れ発生	

[0025]
[Effect of the Invention] By the invention in this application, the manufacture yield of the bellows of the ferritic stainless steel which was cheap and was excellent in stress-corrosion-cracking-proof nature which does not contain expensive nickel improved greatly. Although processing of the bellows of a ferritic stainless steel was attained, and the destruction at the time of manufacture occurred mostly and had caused the rise of a manufacturing cost conventionally compared with the austenitic stainless steel, the manufacture yield improves as a result of this invention, and it could be given by the advantage of nickel not being included also in respect of cost. The effect acquired by this becomes what also has the temporarily immense social profits which the effect that disclosure of the detrimental liquid and gas resulting from the crack initiation of stress corrosion cracking or fatigue breaking is solved, and contamination in respect of environment is lost is acquired, and do not appear in direct economic effects as well as the economic earnings from a industrial field.

[Translation done.]

TECHNICAL FIELD

[Industrial Application] this invention relates to the ferritic stainless steel for bellows used for piping of an automobile exhaust air system and gas, and a water pipe.

[Translation done.]

PRIOR ART

[Description of the Prior Art] The bellows pipe is used for the purpose of absorbing the distortion and vibration by heat as piping, such as a gas and a liquid. Conventionally, the copper alloy and the austenitic stainless steel have been used for this bellows. This reason is because it was difficult with the metal of others [processing / to bellows structure]. That is, a copper alloy and an austenitic stainless steel have the large elongation between the colds, and it is the optimal material for the bellows which applies bulging fabricated by elongation. On the other hand, since ductility ran short, bulging of the metal which consists of bcc crystals, such as carbon steel, was not completed.
[0003] On the other hand, depending on the corrosive solution passing through the interior, there was a fault that stress corrosion cracking tends to generate the bellows made from an austenitic stainless steel although manufacture is easy. In order to absorb distortion and vibration by bending of the mountain for heights of a pipe, and the valley for a crevice, stress surely applies [this] bellows to a part for a part for heights, and a crevice. That is, removal of stress is impossible structure and parts. Nevertheless, an austenitic stainless steel is the high alloy of stress corrosion crack sensitivity. For this reason, the bellows made from an austenitic stainless steel had the fault of being very easy to generate stress corrosion cracking.
[0004] In order to avoid stress corrosion cracking, it is one of whether it considers as the structure where whether a low material of stress corrosion crack sensitivity being used and the structure, i.e., a stress load, where stress corrosion cracking cannot occur easily structurally do not remain. In order to reduce the stress corrosion crack sensitivity of an austenitic stainless steel, nickel content is made to increase and reducing Cr, N, Mo, and P is proposed as indicated by JP,49-107915,A. However, even if it used such steel, by the time it prevented generating of stress corrosion cracking only by the time to stress-corrosion-cracking generating being extended suitably, it did not result.
[0005] On the other hand, the number of the irregularity of bellows is increased structurally, or it is making angle of bend of a crevice or heights small, and considers reducing the stress which distributes stress and is applied to each crevice or heights. However, since bellows became large or became long, this method had the fault to which cost becomes high -- equipment also has the need of enlarging. And still, it did not cancel but the susceptibility of stress corrosion cracking has been afflicted by stress corrosion cracking depending on environment.
[0006] On the other hand, this invention person etc. succeeded in manufacturing the bellows which limited the surface roughness of a ferritic-stainless-steel board, and canceled stress corrosion crack sensitivity as a matter of fact.

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EFFECT OF THE INVENTION

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TECHNICAL PROBLEM

[Problem(s) to be Solved by the Invention] However, although it succeeded in processing of the bellows of a ferritic stainless steel, the fracture accident presumed to be based on the shortage of ductility of a material at the mountain portion of bellows or the edge of a processing part especially at the time of processing was produced in many cases, and the yield was **** very much compared with processing of an austenitic stainless steel. Then, in order to improve the ductility of a material, it examined by reducing C and N to a limit based on knowledge conventionally, and raising the ductility of a material. However, although the ductility by the tension test of a material improved, fracture accident did not necessarily decrease at the edge of the mountain portion of bellows, or a processing portion. Furthermore, although the influence by inclusion or the sludge was considered and the fracture fracture surface was observed in detail, it did not come to check them.
[0008] Thus, it was surmised that the processing crack at the time of bellows processing had a cause in the shortage of ductility of a material and properties other than existence of inclusion and a sludge. this invention is to utilize the knowledge and offer the ferritic stainless steel which raises the yield productivity of bellows processing without crack generating based on having found out that generating of a crack related to surface irregularity.

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MEANS

[Means for Solving the Problem] this invention person etc. admitted that the irregularity of a material originated and destruction occurred as causes other than the shortage of ductility, and existence of inclusion and a sludge, as a result of performing examination detailed about the cause of generating of the destruction generated at the time of bellows processing of a ferritic stainless steel. That is, stress concentrated on the portion to which board thickness is small locally with the irregularity on the front face of a material, and the phenomenon which fracture generates with there [as the starting point] was found out. It is common sense for this contractor that fracture occurs from the notching section in the tension test which added notching. However, when compared with notching of a test piece, it newly found out that concentration of local stress occurred and the irregularity on a small minute front face might also serve as an origin of fracture overwhelmingly.

[0010] Then, this invention person etc. is stopping the minute irregularity on a front face as much as possible, and tried to reduce the processing crack of bellows as much as possible. The hydrostatic bulge test was performed by the ferritic stainless steel to which arithmetic mean granularity Ra of ****** was reduced as much as possible first, and crack nature was evaluated. Bulging was performed until it fractured, and the examination estimated crack sensitivity from the forming height at the time of fracture. In an exam, a processing crack [in / bellows processing / in the one where the forming height at the time of fracture is larger] shall decrease. However, by reducing Ra, on the average, although forming height rose, in inside, what has extremely low forming height generated it. And when [this] the surface state of a material with low forming height was analyzed in detail extremely, compared with the material of forming height with the average value of the maximum depth Rv, the large thing became clear. However, the more Ra and the value of Rv were small, forming height did not become high but, the more they were also understood that there is a limitation. This reason is presumed for the lubrication between the metal mold which presses down a part for a flange to become inadequate from the surface situation of mold goods, and for elongation to concentrate at the peak of bulging although it is under examination wholeheartedly.

[0011] this invention is made based on the above knowledge. The 1st invention is the ferritic stainless steel which reforms a surface state based on the material which has high ductility, limited the upper limit of Content C and the amount of N in order to secure sufficient ductility of the material itself, and limited the upper limit of Rv. That is, at weight %, it is C. : 0.02% or less Less than [more than Cr:10.0 23.0%], N : In the ferritic stainless steel containing 0.015% or less, surface roughness is the ferritic-stainless-steel board for bellows characterized by 0.2-micrometer or more being 2.00 micrometers or less by arithmetic mean granularity Ra in 0.04-micrometer or more 0.5 micrometers or less and the maximum depth Rv.

[0012] Moreover, bellows is used in many cases with absorption and the fused salt corrosive environment of an intense vibration or distortion. For oscillating absorption and distorted absorption, still more sufficient ductile reservation for a material is required. therefore, Ti -- and -- or steel which added Nb is considered as the 2nd invention That is, it is C at weight %. : 0.02% or less, Si: Less than [1.0%], less than [Mn:1.0%], Cr: Less than [more than 10.0 23.0%], N : It adds further 0.015% or less. Are 7 or more times of the sum of a Nb:C content and N content, are 4 or more times of the sum of 0.6% or less, a Ti:C content, and N content, and 0.6% or less of one sort or two sorts are included. In addition, it is the ferritic stainless steel which consists of an unescapable impurity and Fe. Surface roughness is the ferritic-stainless-steel board for bellows characterized by 0.2-micrometer or more being 2.00 micrometers or less by arithmetic mean granularity Ra in 0.04-micrometer or more 0.5 micrometers or less and the maximum depth Rv.

[0013] On the other hand, the gas and liquid which pass through the interior may be applied to a corrosive high object. It is effective to add one sort of Mo, Cu, and nickel or two sorts or more corresponding to the corrosion-resistant level demanded for such a use, and such a ferritic stainless steel is considered as the 3rd invention. That is, at weight %, it is C. : 0.02% or less, Si: Less than [1.0%], less than [Mn:1.0%], Cr: Less than [more than 10.0 23.0%], N : 0.015% or less is contained. further Less than [Mo:2.0%], One sort less than [nickel:1.0%] and not more than Cu:0.8% or two sorts or more are included. Surface roughness is the ferritic-stainless-steel board for bellows characterized by 0.2-micrometer or more being 2.00 micrometers or less by arithmetic mean granularity Ra in 0.04-micrometer or more 0.5 micrometers or less and the maximum depth Rv.

[0014] Furthermore, to the bellows used in intense oscillating absorption and a corrosion foods environment, addition of addition and Mo of Ti or Nb, and nickel and Cu is effective, and considers this ferritic stainless steel as the 4th invention. That is, at weight %, it is C. : 0.02% or less, Si: Less than [1.0%], less than [Mn:1.0%], Cr: Less than [more than 10.0 23.0%], N : 0.015% or less is included. Furthermore it is 7 or more times of the sum of a Nb:C content and N content, and is 4 or more times of the sum of 0.6% or less, a Ti:C content, and N content, and 0.6% or less of one sort or two sorts are included. further again Less than Mo:2.0%], One sort less than [nickel:1.0%] and not more than Cu:0.8% or two sorts or more are included. In addition, it is the

ferritic stainless steel which consists of an unescapable impurity and Fe. Surface roughness is the ferritic-stainless-steel board for bellows characterized by 0.2-micrometer or more being 2.00 micrometers or less by arithmetic mean granularity Ra in 0.04-micrometer or more 0.5 micrometers or less and the maximum depth Rv.

[0015] Next, the reason for limitation of this invention is explained. Although C dissolves to an invaded type and intensity is made to increase, it is the element in which ductility is reduced. So, in order [being enough] to carry out ductility reservation, the upper limit was made into 0.02% by weight %. Si is an element which degrades hot-working nature. So, the upper limit was limited with 1.0% by weight %.

[0016] Mn is an effective element in order to make S which is the detrimental impurity which lowers hot-working nature fix. However, processing of bellows will become difficult, if a lot of addition reduces ductility and it adds especially exceeding 1.0%. Then, the addition was made into 1.0%. Although Cr is the fundamental component of stainless steel, a lot of addition reduces ductility. Then, the upper limit was made into 23.0% by weight %. The minimum could be 10.0% in order to secure corrosion resistance.

[0017] Ti and Nb are the dissolution elements of powerful C and N, and decrease Dissolution C and the amount of N. Consequently, ductility improves. Since the addition needed to make C and N fix completely in stoichiometry as TiC and TiN, or NbC and NbN, in the case of Ti, it made the minimum 4 times of the amount of content C, and the amount of content N by weight %, and, in Nb, made it 7 times. However, it was set up by Ti, and since it became remarkable Dissolution Ti and ductility falling the addition which exceeds 1.0% exceeding 0.6% the case of Ti in Nb according to a Nb independent, the upper limit was set up with 1.0% by Nb 0.6% by weight %. N has the same effect as C. So, since it had sufficient ductility for bellows processing, in N, the upper limit was made into 0.015% by weight %.

[0018] Although both Mo, nickel, and Cu are effective in raising corrosion resistance, a lot of addition reduces ductility. Especially, in the case of Mo, 2.0%, in the case of nickel, if it adds exceeding 0.8% in 1.0% and Cu, ductility will fall, and processing of bellows becomes difficult. Then, it limited in Mo and, as for the case of Cu, it limited the addition with 0.8% or less 1.0% or less with nickel 2.0% or less.

[0019] On the other hand, the value of arithmetic mean granularity Ra and the maximum depth Rv was limited from evaluation of forming height from the result of a hydrostatic bulge test. If Ra and Rv are large, stress will concentrate and fracture to the irregularity on a minute front face. However, even if Ra and Rv are too small, forming height decreases. This was considered because lubrication with metal mold fell at the time of processing of bellows. Then, 0.04-micrometeror more 0.5 micrometers or less and Rv were limited for Ra to processing of bellows with 0.2 micrometers or more 2.00 micrometers or less from evaluation of the forming height of a hydrostatic bulge test as a surface state of the steel plate which a crack does not produce.

[Translation done.]

OPERATION

[Function] this invention offers the ferritic stainless steel for bellows processing which can decrease the destruction which is easy to generate at the time of processing to bellows. The ferritic stainless steel of a base material becomes possible [securing the difference of the path of the heights of bellows, and a crevice enough] by limiting the content of C and N to low level. Furthermore, the lubrication to a lubricating oil with the metal mold at the time of bellows processing succeeds in fabrication of bellows without a processing crack in the good state by setting Ra to 0.04 micrometers or more 0.5 micrometers or less, and setting the value of Rv to 0.2 micrometers or more 2.00 micrometers or less. Consequently, the yield improves because the processing crack from which minute irregularity becomes a cause decreases and the crack at the time of bellows processing decreases remarkably.

[0021] When a material component reduces 0.02% or less and the amount of content N for the amount of content C even to 0.015% by weight % by weight %, ductility is fully secured. Moreover, still higher ductility is secured by depositing C and N as Ti and a Nb compound by addition of Ti and Nb, and it becomes usable as a material for bellows in the environment where intense oscillating absorption or absorption of distortion is required. The lower limit made Ti and Nb addition 4 times of the sum of the amount of content C, and the amount of content N by Ti, and made them 7 times of the sum of the amount of content C, and the amount of content N by Nb. A upper limit can secure the high ductility demanded by considering as 1.0% by0.6 and Nb by weight % at Ti. Addition of Mo, nickel, and Cu raises the corrosion resistance of a material, and can offer the material for bellows used under the environment where corrosion resistance is required by those addition.

[Translation done.]

EXAMPLE

[Example] The bellows tubing test result of the steel plate which contains the chemical composition shown in Table 1 as A-H, respectively is shown with arithmetic mean granularity Ra and the maximum surface depth Rv. The value of Rv was measured based on the test method of JISB0601. The cut-off value was [the evaluation length of measurement conditions] 4mm in 0.8mm. The result of a bellows processing examination was performed by the existence of a crack.
[0023] From Table 1, the crack by bellows processing was not generated in No.A-E which is this invention steel. This invention steel and comparison steel are [0.04 micrometeror more 0.5 micrometers or less and Rv of Ra] 0.2 micrometers or more 2.00 micrometers or less. However, a processing crack produces the comparison steel F and Rv is 2.00 micrometers or more. Moreover, in the comparison steel G which the processing crack produced similarly, Ra is smaller than 0.04 micrometers. In the comparison steel F, minute irregularity exists on a front face and what the crack generated because the stress at the time of processing concentrates on this irregularity is presumed. On the other hand, in the comparison steel G, although there is little irregularity with a conversely minute front face, lubrication with metal mold is presumed to be what broke because the stress added at the time of processing does not join the whole material but concentrates on eye an inadequate hatchet only at bellows heights. Moreover, although the comparison steel H has Ra and Rv in a generic claim, since the amount of content C is over 0.02%, what the ductility insufficient shell bellows processing crack of the material itself produced is presumed.
[0024]
[Table 1]

No.	C	Si	Mn	Cr	Ti	N	Ni	Mo	Nb	Cu	Ra (μm)	Rv (μm)	加工試験	
A	0.012	0.25	0.33	16.30	0.37	0.010	0.05	—	—	—	0.06	1.26	割れ無し	発明鋼
B	0.010	0.50	0.01	11.05	0.23	0.005	—	—	—	—	0.04	0.24	割れ無し	
C	0.005	0.34	0.50	16.10	—	0.008	—	—	—	—	0.24	0.92	割れ無し	
D	0.001	0.11	0.09	17.14	0.18	0.010	—	1.2	—	—	0.07	0.40	割れ無し	
E	0.013	0.30	0.12	19.15	—	0.010	—	—	0.40	0.60	0.20	0.35	割れ無し	
F	0.005	0.10	0.13	17.20	0.23	0.007	—	—	—	—	0.20	2.10	割れ発生	比較鋼
G	0.013	0.30	0.15	19.15	0.05	0.015	—	—	—	—	0.03	1.00	割れ発生	
H	0.047	0.44	0.33	18.27	—	0.003	—	—	—	—	0.06	1.22	割れ発生	

[Translation done.]

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INVENTOR-INFORMATION:

NAME	COUNTRY
TAKADA, TAKESHI	
YAMAMOTO, AKIO	

ASSIGNEE-INFORMATION:

NAME	COUNTRY
NIPPON STEEL CORP	

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ABSTRACT:

PURPOSE: To provide a ferritic stainless steel plate for bellows, excellent in stress corrosion cracking resistance.

CONSTITUTION: This ferritic stainless steel plate for bellows has a composition consisting of, by weight, ≤0.02% C, 10.0-23.0% Cr, ≤0.015% N, and Fe with inevitable impurities, further containing, if necessary, ≤1.0% Si and ≤1.0% Mn, further containing, if necessary, either or both of Nb in the amount ≥7times the total content of C and N and not higher than 0.6% and Ti in the amount ≥4times the total content of C and N and not higher than 0.6%, and further containing, if necessary, one or ≤2 kinds among ≤2.0% Mo, ≤1.0% Ni, and ≤0.8% Cu. Moreover, in this steel plate, surface roughness is regulated to 0.04-0.5μm by arithmetic mean roughness Ra and to 0.2-2.00μm by maximum height Rv.

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(71)出願人　000006655
新日本製鐵株式会社
東京都千代田区大手町２丁目６番３号

(72)発明者　高田　健
千葉県富津市新富20－1　新日本製鐵株式会社技術開発本部内

(72)発明者　山本　章夫
千葉県富津市新富20－1　新日本製鐵株式会社技術開発本部内

(74)代理人　弁理士　田村　弘明　（外1名）

(54)【発明の名称】　ベローズ用フェライト系ステンレス鋼板

(57)【要約】　（修正有）

【目的】　耐応力腐食割れ性に優れたベローズ用フェライト系ステンレス鋼板を提供する。

【構成】　重量%で、Ｃ：０．０２%以下、Ｃｒ：１０．０以上２３．０%以下、Ｎ：０．０１５%以下、さらに必要によりＳｉ：１．０%以下、Ｍｎ：１．０%以下を含み、さらに必要によりＮｂ：Ｃ含有量とＮ含有量の和の７倍以上でかつ０．６%以下、Ｔｉ：Ｃ含有量とＮ含有量の和の４倍以上でかつ０．６%以下の１種もしくは２種を含み、さらに必要によりＭｏ：２．０%以下、Ｎｉ：１．０%以下、Ｃｕ：０．８%以下の１種もしくは２種以上を含み、その他不可避的不純物およびＦｅからなるフェライト系ステンレス鋼において、表面粗さが算術平均粗さＲａで０．０４μｍ以上０．５μｍ以下かつ最大深さＲｖで０．２μｍ以上２．００μｍ以下である、ベローズ用フェライト系ステンレス鋼板。

【特許請求の範囲】

【請求項1】 重量%で

C ：0．02%以下、

Cr：10．0以上23．0%以下、

N ：0．015%以下を含むフェライト系ステンレス鋼において、表面粗さが算術平均粗さRaで0．04μm以上0．5μm以下かつ最大深さRvで0．2μm以上2．00μm以下であることを特徴とする、ベローズ用フェライト系ステンレス鋼板。

【請求項2】 重量%で

C ：0．02%以下、

Si：1．0%以下、

Mn：1．0%以下、

Cr：10．0以上23．0%以下、

N ：0．015%以下、さらに

Nb：C含有量(%)とN含有量(%)の和の7倍以上でかつ0．6%以下

Ti：C含有量(%)とN含有量(%)の和の4倍以上でかつ0．6%以下の1種もしくは2種を含み、その他不可避的不純物およびFeからなるフェライト系ステンレス鋼において、表面粗さが算術平均粗さRaで0．04μm以上0．5μm以下かつ最大深さRvで0．2μm以上2．00μm以下であることを特徴とする、ベローズ用フェライト系ステンレス鋼板。

【請求項3】 重量%で

C ：0．02%以下、

Si：1．0%以下、

Mn：1．0%以下、

Cr：10．0以上23．0%以下、

N ：0．015%以下、さらに

Mo：2．0%以下、

Ni：1．0%以下、

Cu：0．8%以下の1種もしくは2種以上を含み、その他不可避的不純物およびFeからなるフェライト系ステンレス鋼において、表面粗さが算術平均粗さRaで0．04μm以上0．5μm以下かつ最大深さRvで0．2μm以上2．00μm以下であることを特徴とする、ベローズ用フェライト系ステンレス鋼板。

【請求項4】 重量%で

C ：0．02%以下、

Si：1．0%以下、

Mn：1．0%以下、

Cr：10．0以上23．0%以下、

N ：0．015%以下、さらに

Nb：C含有量(%)とN含有量(%)の和の7倍以上でかつ0．6%以下

Ti：C含有量(%)とN含有量(%)の和の4倍以上でかつ0．6%以下の1種もしくは2種を含み、さらに

Mo：2．0%以下、

Ni：1．0%以下、

Cu：0．8%以下の1種もしくは2種以上を含み、その他不可避的不純物およびFeからなるフェライト系ステンレス鋼であって、表面粗さが算術平均粗さRaで0．04μm以上0．5μm以下かつ最大深さRvで0．2μm以上2．00μm以下であることを特徴とする、ベローズ用フェライト系ステンレス鋼板。

【発明の詳細な説明】

【0001】

【産業上の利用分野】本発明は自動車排気系、ガスの配管、水道管に使用されるベローズ用フェライト系ステンレス鋼に関するものである。

【0002】

【従来の技術】ベローズ管は気体、液体等の配管として、熱による歪や振動を吸収するのを目的として使用されている。従来、このベローズには銅合金やオーステナイト系ステンレス鋼が用いられてきた。この理由は、ベローズ構造への加工が他の金属では困難であったためである。すなわち、銅合金やオーステナイト系ステンレス鋼は、冷間での伸びが大きく、伸びによって成形されるバルジ加工を適用するベローズには最適の材料である。これに対して、炭素鋼等のbcc結晶からなる金属は延性が不足するためにバルジ加工ができなかった。

【0003】一方、オーステナイト系ステンレス鋼製ベローズは、製造は容易であるものの、内部を通る腐食性の溶液によっては応力腐食割れが発生し易いという欠点があった。これは、ベローズは管の凸部分の山と凹部分の谷の曲げによって歪や振動を吸収するために、凸部分と凹部分には必ず応力が掛かる。すなわち、応力の除去は不可能な構造、部品である。それにもかかわらずオーステナイト系ステンレス鋼は、応力腐食割れ感受性の高い合金である。このため、オーステナイト系ステンレス鋼製のベローズは応力腐食割れが極めて発生し易いという欠点があった。

【0004】応力腐食割れを回避するために、応力腐食割れ感受性の低い材料を用いるか、構造的に応力腐食割れが起きにくい構造すなわち応力負荷が残らない構造とするかのどちらかである。オーステナイト系ステンレス鋼の応力腐食割れ感受性を低減するためには、例えば特開昭49－107915号公報に記載されているように、Ni含有量を増加させ、Cr，N，Mo，Pを低減することが提案されている。しかし、このような鋼を用いても応力腐食割れ発生までの時間が相応に伸びるだけで応力腐食割れの発生を防止するまでには至らなかった。

【0005】一方、構造的にはベローズの凹凸の数を増やしたり凹部や凸部の曲げ角度を小さくすることで、応力を分散してひとつひとつの凹部ないし凸部に掛かる応力を低下させることが考えられている。しかしこの方法は、ベローズが大きくなったり長くなるため装置も大きくする必要があるなど、コストが高くなる欠点があっ

た。しかも、それでも応力腐食割れの感受性は解消せず、環境によっては応力腐食割れに悩まされてきた。

【0006】これに対し本発明者等は、フェライト系ステンレス鋼板の表面粗さを限定して事実上応力腐食割れ感受性を解消したベローズを製造することに成功した。

【0007】

【発明が解決しようとする課題】しかし、フェライト系ステンレス鋼のベローズの加工に成功したとはいえ、加工時に特にベローズの山部分や加工部位の端部で素材の延性不足によると推定される破断事故を生ずることが多く、歩留りはオーステナイト系ステンレス鋼の加工に比べて極めて劣位であった。そこで素材の延性を改善するために、従来知見に基づいてＣやＮを極限まで低減し素材の延性を向上させて試験を行った。ところが、素材の引張試験による延性は向上したにもかかわらず、必ずしもベローズの山部分や加工部分の端部で破断事故は減少しなかった。更に、介在物あるいは析出物による影響を考え破断破面を詳細に観察したが、それらを確認するには至らなかった。

【0008】このように、ベローズ加工時の加工割れは、素材の延性不足や、介在物、析出物の存在以外の特性に原因があると推測された。本発明は、割れの発生が表面の凹凸に関連することを見出したことに基づき、その知見を活用して、割れ発生がないベローズ加工の歩留り生産性を向上させるフェライト系ステンレス鋼を提供することにある。

【0009】

【課題を解決するための手段】本発明者等は、フェライト系ステンレス鋼のベローズ加工時に発生する破壊の発生原因について詳細な検討を行った結果、延性不足、介在物や析出物の存在以外の原因として、素材の凹凸が起因して破壊が発生することを認めた。すなわち、素材表面の凹凸により局所的に板厚が小さくなっている部分に応力が集中し、そこを起点として破断が発生する現象を見いだしたのである。切り欠きを加えた引張試験では切り欠き部から破断が発生することは当業者にとって常識である。しかしながら、試験片の切り欠きに比べたら圧倒的に小さい微小な表面上の凹凸も局所的な応力の集中が発生し、破断の起点となり得ることを新たに見いだしたのである。

【0010】そこで、本発明者等は、表面上の微小な凹凸を極力抑えることで、ベローズの加工割れを極力低減させることを試みた。まず表面粗の算術平均粗さＲａを極力低下させたフェライト系ステンレス鋼で液圧バルジ試験を行い、割れ性の評価を行った。試験では破断するまでバルジ加工を行い、破断時の成形高さから割れ感受性を評価した。本試験では破断時の成形高さが大きい方が、ベローズ加工における加工割れが減少するものとした。しかし、Ｒａを低減することで成形高さは平均的には上昇したものの、中には極端に成形高さの低いものが発生した。そして、この極端に成形高さの低い素材の表面状態を詳細に解析したところ、最大深さＲｖの値が平均的な成形高さの素材に比べて大きいことが判明した。ところが、ＲａやＲｖの値は小さければ小さい程成形高さが高くなるのではなく、限界があることも分かった。この理由は、鋭意検討中であるが成形品の表面状況から、フランジ部分を押える金型との間の潤滑が不十分となってバルジ加工の頂点で伸びが集中するためと推定している。

【0011】本発明は、以上の知見を基になされたものである。第１の発明は高延性を有する材料を基に表面状態を改質するもので、素材そのものの十分な延性を確保するために含有ＣおよびＮ量の上限を限定し、かつＲｖの上限を限定したフェライト系ステンレス鋼である。すなわち重量%で、Ｃ ：０．０２%以下、 Ｃｒ：１０．０以上２３．０%以下、Ｎ ：０．０１５%以下を含むフェライト系ステンレス鋼において、表面粗さが算術平均粗さＲａで０．０４μm以上０．５μm以下かつ最大深さＲｖで０．２μm以上２．００μm以下であることを特徴とする、ベローズ用フェライト系ステンレス鋼板である。

【0012】また、ベローズは激しい振動、あるいは歪みの吸収および溶融塩腐食環境で使用される場合が多い。振動吸収および歪の吸収のためには、素材には更に十分な延性の確保が要求される。そのために、Ｔｉおよび、あるいはＮｂを添加した鋼を第２の発明とする。すなわち、重量%で、Ｃ ：０．０２%以下、 Ｓｉ：１．０%以下、Ｍｎ：１．０%以下、 Ｃｒ：１０．０以上２３．０%以下、Ｎ ：０．０１５%以下、さらに加えて、Ｎｂ：Ｃ含有量とＮ含有量の和の７倍以上でかつ０．６%以下、Ｔｉ：Ｃ含有量とＮ含有量の和の４倍以上でかつ０．６%以下の１種もしくは２種を含み、その他不可避的不純物およびＦｅからなるフェライト系ステンレス鋼であって、表面粗さが算術平均粗さＲａで０．０４μm以上０．５μm以下かつ最大深さＲｖで０．２μm以上２．００μm以下であることを特徴とする、ベローズ用フェライト系ステンレス鋼板である。

【0013】一方、内部を通過する気体、液体は腐食性の高い物に適用する場合がある。この様な用途のために要求される耐食性レベルに対応してＭｏ，Ｃｕ，Ｎｉの１種または２種以上を添加することは有効であり、この様なフェライト系ステンレス鋼を第３の発明とする。すなわち重量%で、Ｃ ：０．０２%以下、 Ｓｉ：１．０%以下、Ｍｎ：１．０%以下、 Ｃｒ：１０．０以上２３．０%以下、Ｎ ：０．０１５%以下を含有し、さらにＭｏ：２．０%以下、 Ｎｉ：１．０%以下、Ｃｕ：０．８%以下の１種もしくは２種以上を含み、表面粗さが算術平均粗さＲａで０．０４μm以上０．５μm以下かつ最大深さＲｖで０．２μm以

上2．00μm以下であることを特徴とする、ベローズ用フェライト系ステンレス鋼板である。

【0014】更に、激しい振動吸収と腐食食環境で使用されるベローズに対しては．Tiあるいは Nbの添加およびMoおよびNiおよびCuの添加が有効であり、このフェライト系ステンレス鋼を第4の発明とする。すなわち重量%で．C ：0．02%以下．　Si：1．0%以下．Mn：1．0%以下．　Cr：10．0以上23．0%以下．N ：0．015%以下を含み．さらにNb：C含有量とN含有量の和の7倍以上でかつ0．6%以下、Ti：C含有量とN含有量の和の4倍以上でかつ0．6%以下の1種もしくは2種を含み．さらにまた．Mo：2．0%以下．　Ni：1．0%以下．Cu：0．8%以下の1種もしくは2種以上を含み、その他不可避的不純物およびFeからなるフェライト系ステンレス鋼であって．表面粗さが算術平均粗さRaで0．04μm以上0．5μm以下かつ最大深さRvで0．2μm以上2．00μm以下であることを特徴とする．ベローズ用フェライト系ステンレス鋼板である。

【0015】次に、本発明の限定理由について説明する。Cは侵入型に固溶し強度を増加させるが、延性を低下させる元素である。それ故、十分な延性確保するために．上限を重量%で0．02%とした。Siは．熱間加工性を劣化させる元素である。それ故．上限を重量%で1．0%と限定した。

【0016】Mnは、熱間加工性を下げる有害な不純物であるSを固着させるために有効な元素である。しかし．多量の添加は延性を低下させ、特に1．0%を超えて添加するとベローズの加工が困難になる。そこで、添加量を1．0%とした。Crはステンレス鋼の基本成分であるが、多量の添加は延性を低下させる。そこで上限を重量%で23．0%とした。下限は耐食性を確保するため10．0%とした。

【0017】TiおよびNbは、強力なC，Nの固溶元素であり、固溶C，N量を減少させる。その結果．延性は向上する。添加量はTiCおよびTiNあるいはNbCおよびNbNとしてCおよびNを量論的に完全に固着させる必要があるので、重量%で下限をTiの場合含有C量と含有N量の4倍とし．Nbの場合7倍とした。しかし．Tiの場合0．6%を超えて．Nbの場合1．0%を超えての添加は固溶TiおよびNb単独による延性低下が顕著となるので、上限を重量%でTiで0．6%．Nbで1．0%と設定した。Nは．Cと同様の効果を有する。それ故ベローズ加工に十分な延性を有するため．Nの場合にはその上限を重量%で0．015%とした。

【0018】Mo，Ni．Cuはともに耐食性を向上させるのに有効であるが、多量の添加は延性を低下させる。特にMoの場合は2．0%、Niの場合は1．0%．Cuの場合は0．8%を超えて添加すると．延性が低下してベローズの加工が困難になる。そこで．添加量をMoでは2．0%以下．Niでは1．0%以下．Cuの場合は0．8%以下と限定した。

【0019】一方、算術平均粗さRaおよび最大深さRvの値は、液圧バルジ試験の結果より．成形高さの評価から限定した。RaやRvが大きいと．微小な表面上の凹凸に応力が集中し破断してしまう。しかし、RaやRvが小さすぎても、成形高さは減少する。このことは、ベローズの加工時に金型との潤滑が低下したためと考えられた。そこで．液圧バルジ試験の成形高さの評価から．ベローズの加工に割れが生じない鋼板の表面状態として．Raを0．04μm以上0．5μm以下かつRvを0．2μm以上2．00μm以下と限定した。

【0020】

【作用】本発明は、ベローズへの加工時に発生し易い破壊を減少し得るベローズ加工用のフェライト系ステンレス鋼を提供する。母材のフェライト系ステンレス鋼は、CおよびNの含有量を低いレベルに限定することによって．ベローズの凸部と凹部の径の差を十分確保することが可能となる。更に、Raを0．04μm以上0．5μm以下にし、かつRvの値を0．2μm以上2．00μm以下にすることで、ベローズ加工時の金型との潤滑油による潤滑が良好な状態で加工割れなくベローズの成形に成功する。この結果、微小な凹凸が原因となる加工割れが低減して．ベローズ加工時の割れは著しく減少することで歩留りは向上する。

【0021】素材成分は．含有C量を重量%で0．02%以下かつ含有N量を重量%で0．015%にまで低減させることにより、延性が十分に確保される。またTiおよびNbの添加によりCおよびNをTiおよびNb化合物として析出させることで更に高い延性が確保され、激しい振動吸収あるいは歪みの吸収が要求される環境でのベローズ用素材としての使用が可能となる。TiおよびNb添加量は下限値はTiでは含有C量と含有N量の和の4倍とし．Nbでは含有C量と含有N量の和の7倍とした。上限値は重量%でTiで0．6とNbで1．0%とすることで要求される高延性が確保できる。Mo，Ni．Cuの添加は素材の耐食性を向上させ、それらの添加により、耐食性が要求される環境下で使用されるベローズ用素材が提供できる。

【0022】

【実施例】表1に、A～Hとして示す化学成分をそれぞれ含有する鋼板のベローズ管成形試験結果を算術平均粗さRa、最大表面深さRvとともに示す。Rvの値はJISB0601の試験方法に準拠して測定した。測定条件は．カットオフ値が0．8㎜で評価長さが4㎜であった。ベローズ加工試験の結果は割れの有無で行った。

【0023】表1から、本発明鋼であるNo．A～Eでは．ベローズ加工による割れは発生しなかった。本発明

鋼、比較鋼ともＲａは０．０４μｍ以上０．５μｍ以下かつＲｖが０．２μｍ以上２．００μｍ以下である。しかし、比較鋼Ｆは加工割れが生じ、Ｒｖが２．００μｍ以上である。また同様に加工割れが生じた比較鋼ＧではＲａが０．０４μｍより小さい。比較鋼Ｆでは、表面上に微小な凹凸が存在し、この凹凸に加工時の応力が集中することで割れが発生したものと推定される。一方、比較鋼Ｇでは逆に表面の微小な凹凸は少ないが、金型との潤滑が不十分なために、加工時に加わる応力が素材全体に加わらずベローズ凸部にのみ集中することで割れたものと推定される。また、比較鋼ＨはＲａ，Ｒｖともに請求範囲内にあるが、含有Ｃ量が０．０２％を超えているために、素材そのものの延性不足からベローズ加工割れが生じたものと推定される。

【００２４】

【表１】

No.	C	Si	Mn	Cr	Ti	N	Ni	Mo	Nb	Cu	Ra (μm)	Rv (μm)	加工試験	
A	0.012	0.25	0.33	16.30	0.37	0.010	0.05	—	—	—	0.06	1.26	割れ無し	発明鋼
B	0.010	0.50	0.01	11.05	0.23	0.005	—	—	—	—	0.04	0.24	割れ無し	
C	0.005	0.34	0.50	16.10	—	0.008	—	—	—	—	0.24	0.92	割れ無し	
D	0.001	0.11	0.09	17.14	0.18	0.010	—	1.2	—	—	0.07	0.40	割れ無し	
E	0.013	0.30	0.12	19.15	—	0.010	—	—	0.40	0.60	0.20	0.35	割れ無し	
F	0.005	0.10	0.13	17.20	0.23	0.007	—	—	—	—	0.20	2.10	割れ発生	比較鋼
G	0.013	0.30	0.15	19.15	0.05	0.015	—	—	—	—	0.03	1.00	割れ発生	
H	0.047	0.44	0.38	18.27	—	0.003	—	—	—	—	0.06	1.22	割れ発生	

【００２５】

【発明の効果】本願発明により、高価なＮｉを含まない安価で耐応力腐食割れ性の優れたフェライト系ステンレス鋼のベローズの製造歩留まりが大きく向上した。従来、フェライト系ステンレス鋼のベローズは加工は可能となったものの、オーステナイト系ステンレス鋼に比べると製造時の破壊が多く発生し、製造コストの上昇を招いていたが、本発明の結果製造歩留まりが向上し、Ｎｉを含まないことの利点がコスト面でも享受できるようになった。これにより得られた効果は、工業的な面からの経済的利益はもちろん、一時的とはいえ応力腐食割れや疲労破壊の亀裂発生に起因する有害な液体や気体の漏洩が解消して環境面での汚染がなくなる効果が得られ、直接経済効果には現れない社会的利益も莫大なものとなる。